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New Oscillator ICs

for operation from 45 to 650 MHz

By G. Kleine

With the introduction of the MAX260x series of oscillator chips from Maxim it is possible to build a stable oscillator circuit with predictable characteristics. An external inductor is all that is necessary to set the centre frequency of the oscillator.

More and more of today’s electronic systems have the need for a good quality, reliable and compact frequency source e.g. radio system local oscillators and phase lock loops (PLL) or microprocessor and data acquisition circuits. The MAX260x series of oscillator chips from Maxim combines an integrated voltage controlled oscillator (VCO) together with on-chip varacter diode and differential output drivers. The differential output can be used as a symmetrical HF output or as two single ended outputs with good decoupling as typically required in PLL applications.

The design of an oscillator circuit for use at HF, VHF and UHF (30 MHz to 1 GHz) is not a trivial exercise. The designer needs to take into account many factors. The circuit must be guaranteed to oscillate under all conditions with extremes of component tolerances and provide an output with good frequency stability and output swing independent of the output loading. If the frequency of oscillation is to be controlled by an external analogue control voltage the oscillator will be a voltage controlled oscillator (VCO) here the design becomes a bit more involved where the control voltage/frequency characteristic must also be considered. A typical discrete VCO is shown as **Figure 1.** Design problems become more acute as the operating frequency of the oscillator increases. Parasitic properties of the components begin to have significant influence on the performance of the design. Layout of the oscillator, inductance of the PCB tracks and other unwanted coupling effects in the circuit must also be taken into account. The oscillator frequency can also be affected by factors such as output loading (also known as load pulling) or changes in its supply voltage (also known as pushing). A good low noise isolated voltage regulator for the oscillator will go a long way to solving this last problem and will also improve the oscillator phase noise performance. The final stage of the design process for a discrete VCO would involve prototype construction and testing under extremes of temperature.

The integrated solution from Maxim

Maxim has introduced a family of integrated oscillators suitable for fixed frequency or narrow band VCO operation. Five different models cover the frequency range from 45 to 650 MHz. These devices allow very simple and compact implementation of an oscillator circuit. (see **Table 1**).

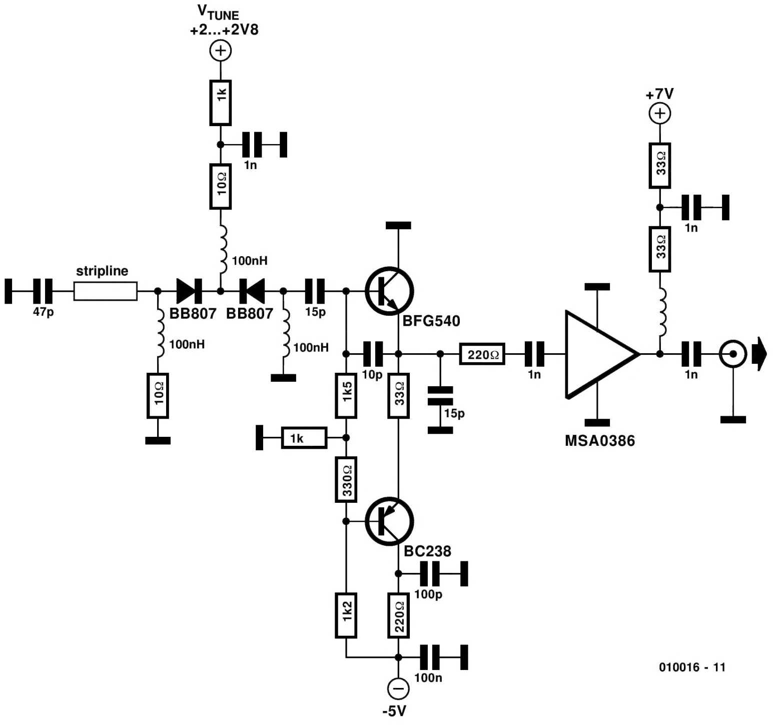

Figure 1. Circuit diagram of a typical discrete VCO.

Table 1 Frequency and inductor range.

Type	Frequency range	Inductance range	min. Q
MAX2605	45 ... 70 MHz	680 ... 2200 nH	35
MAX2606	70 ... 150 MHz	150 ... 820 nH	35
MAX2607	150 ... 300 MHz	39 ... 180 nH	35
MAX2608	300 ... 500 MHz	10 ... 47 nH	40
MAX2609	500 ... 650 MHz	3.9 ... 15 nH	40

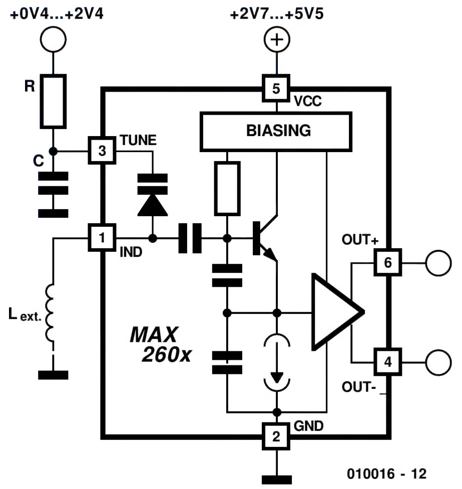

Figure 2. Block diagram of the MAX260x family.

The feedback capacitors and varacter are all integrated on the oscillator chip. To produce a correctly operating VCO it is only necessary to fit an external inductor. The width of the tuning range is such that with 2% tolerance inductors no board-level adjustments or trimming of the VCO is necessary. Once the correct value of inductance is fitted to the oscillator, the VCO is guaranteed to tune to the desired operating frequency.

The MAX260x family operate with a supply voltage of between +2.7 V and +5.5 V, requiring a current of less than 5 mA. A look inside the chip **(Figure 2)** shows that the oscillator design is based on the familiar Colpitts configuration. The feedback capacitor at the base-emitter junction together with the external inductor determine the frequency of oscillation. The built-in varacter diode in the feedback loop allows for the correction of component tolerances of ±3 % by applying an external trimming voltage of between +0.4 V and +2.4 V. The circuit is designed for reliable and stable operation throughout its operating temperature range. The phase noise performance quoted in the data sheet will only be achieved if the Q of the external inductor is greater than that shown in **Table 2.**

A circuit showing a MAX260x configured as a VCO is shown in **Figure 3**. The external inductor is the single component necessary to set the oscillator frequency. The inductance seen at pin 1 (including the PCB track inductance) determines the frequency of oscillation. If the inductor value necessary for your application does not coincide with a value in the standard range then it is possible to use two inductors to achieve the desired value. Choose the biggest value of inductor to have a value just less than the value required, making sure that it meets the minimum Q constraints given in **Table 1**. The second inductor will be a much smaller value and can also have a much lower value of Q. It will not have a great influence on the overall Q of the two inductors. A thin film SMD inductor would be suitable here or at higher frequencies it would be possible to use a PCB track run of the correct length as an inductor.

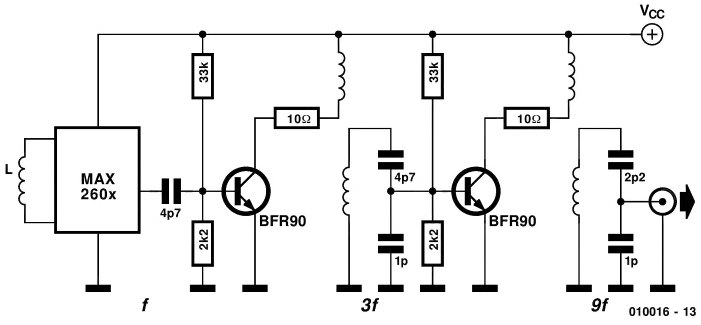

Figure 3. Typical application circuit of the MAX260x.

Shown in **Table 3** is the frequency adjustment range corresponding to a control voltage range of +0.4 V and +2.4 V together with the phase noise performance offset 100 kHz from the carrier.

To ensure that an oscillator can be built that will not require trimming it is important that the tolerance of the two inductors must be less than 2% of their nominal value. At frequencies above about 150 MHz the layout of the circuit and PCB track inductance begin to have a significant influence on the circuit performance. **Table 4** shows standard values of inductors together with the frequency of operation of the VCO. These values should be seen as a starting point for inductor values

Table 2. Technical Data for the MAX260x family.

Type	Vcc	Current consumption	V_{TUNE}	Output power (single ended)	Pushing
MAX2605	+2.7V to +5,5V (max. +6V)	1.9 mA	+0.4 to +2.4 V (max. Vcc +0.3 V)	typ. –10 dBm	60 kHz/V
MAX2606		2.1 mA			120 kHz/V
MAX2607		2.1 mA			220 kHz/V
MAX2608		2.7 mA			480 kHz/V
MAX2609		3.6 mA			720 kHz/V

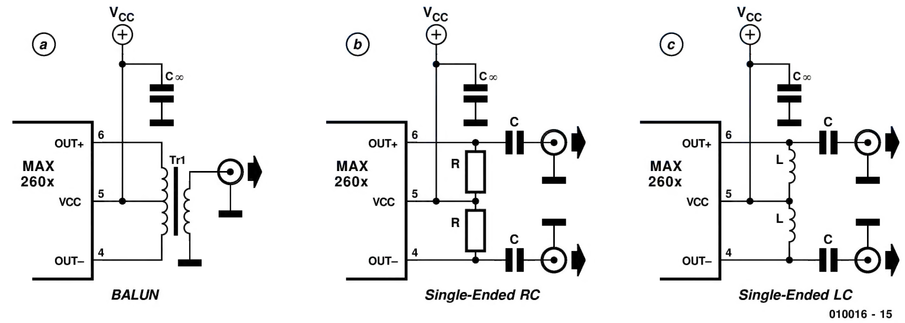

Figure 4. Possible output configurations: a) BALUN, b) RC, c) LC

and the optimal value will be determined once the circuit layout has been built and tested.

Coil selection

Coils suitable for use with the MAX260x series can be obtained from Neosid, Toko and Coilcraft. Toko inductors are distributed by B.E.C. Ltd or Roxburgh Ltd while Coilcraft Products are supplied by Coilcraft Europe. Neosid are supplied by Sterling Components Ltd. **Table 5** shows the recommended series from these suppliers. All the series are SMD inductors. The air-cored coils have plastic formers to enable them to be placed onto the PCB automatically by machine. The air spaced coils have a higher Q than the chip inductors and give a better phase noise performance for the oscillator.

The coil Q factor

Table 1 gives the minimum Q factor necessary of the inductor to guarantee oscillator start-up and ensure that phase noise of the oscillator falls within the specification given in the data sheet. The Q factor or 'goodness' of the inductor is defined as the ratio of the stored energy to the lost energy and can be expressed as:

$$Q = R_p / X_p$$

R_p is the equivalent parallel resistance (the loss resistance) and X_p is the parallel reactance including all the parasitic effects like winding capacitance. It can be seen that for a high Q inductor the losses must be minimised so that R_p is much greater when compared with X_p. This can be achieved by using air spaced or ferrite cored inductors with low eddy current losses.

In contrast to the high Q inductors that we need for the resonant circuit of this oscillator, there are also other types of inductors that are used to suppress unwanted interference in electrical circuits. This type of inductor has a deliberately low Q so that they produce a greater damping effect on unwanted wide-band interference. Using a high Q inductor for interference suppression would have the effect of creating a resonant circuit, increasing interference rather than damping it.

The output stage

The MAX260x series have differential outputs (OUT+, OUT-) both outputs are driven by open collector transistors so it is essential that any circuitry connected to these outputs has a load connected up to Vcc. **Figure 4** shows some of the possible output configurations. The differential outputs can be used directly or can be connected to a balun (balun = balanced to unbalanced converter) to provide a single ended output (**Figure 4a**). Using the differential output mode gives maximum output power with minimum unwanted harmonics. Alternatively, the two outputs can be used independently as in **Figure 4b.** One example would be in a PPL prescaler application where one output drives the frequency divider chain and the other is used as the VCO output signal. The isolation of the two outputs ensures that unwanted noise and side bands from the frequency divider is not superimposed on the VCO output signal. Output impedance matching can be performed with LC circuits as shown in **Figure 4c**.

Figure 5 shows how the two outputs would be employed in a PLL prescaler application. One output drives the PLL divider stage and filter while the second output is used as the local oscillator input to the mixer stage. If the mixer and divider stage were driven by the same output then we would find that interference from the PLL divider circuitry produces interference in the form of sidebands spaced at multiples of the phase detector switching frequency appearing in the wanted signal.

Applications

The MAX260x series of oscillators were designed for use as fixed fre-

Table 3. VCO Frequency Limits and Phase Noise

Type	Frequency limits @ V_{TUNE} = +0.4 V to +2.4 V	Phase noise @ 100 kHz
MAX2605	–2,25 % - +2,25 %	–117 dBc/Hz
MAX2606	–2,5 % - +2,5 %	–112 dBc/Hz
MAX2607	–2,75 % - +2,75 %	–107 dBc/Hz
MAX2608	–2,8 % - +2,8 %	–100 dBc/Hz
MAX2609	–3,0 % - +3,0 %	–93 dBc/Hz

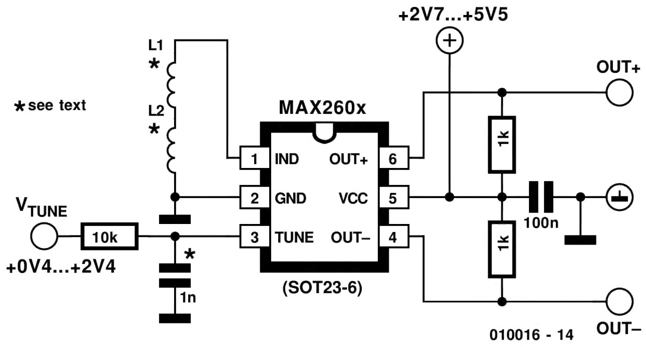

Figure 5. Using the two outputs in a PLL application.

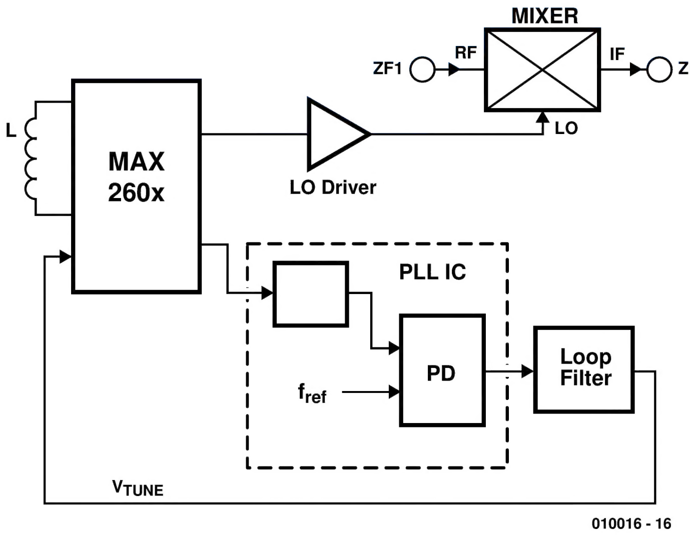

Figure 6. MAX260x with a frequency multiplier.

quency or for narrow band VCO applications. For example conversion oscillators in radio receivers operating at a fixed frequency and connected via a PLL to a reference frequency.

Another application is as a narrowband FM modulator. The operating frequency can be set by a dc voltage applied to the VCO control input, modulated by a superimposed ac signal.

For frequencies above 650 MHz a frequency multiplier circuit can be used (**Figure 6**). Here a transistor stage configured as a class C amplifier is driven by the oscillator output. It switches at the fundamental frequency of the oscillator but because it is producing a square wave it also generates odd harmonic frequencies. The following transistor circuit contains a filter tuned to the harmonic of interest this can usually be the third or fifth (higher harmonics generally have too much attenuation to be of use). Tuning to the fifth harmonic will enable the circuit to operate up to a maximum frequency of 3 GHz with the Maxim series of oscillators. The multiplied frequency is passed through another filter and then to the output.

Table 4. Output frequency and corresponding inductor values.

MAX2605		MAX2606		MAX2607		MAX2608		MAX2609	
L	f	L	f	L	f	L	f*	L	f*
1500 nH	48 MHz	680 nH	75 MHz	150 nH	150 MHz	33 nH	300 MHz	10 nH	500 MHz
1200 nH	55 MHz	470 nH	95 MHz	100 nH	190 MHz	22 nH	350 MHz	8.2 nH	550 MHz
1000 nH	60 MHz	390 nH	100 MHz	68 nH	220 MHz	15 nH	420 MHz	6.8 nH	590 MHz
820 nH	67 MHz	220 nH	130 MHz	47 nH	270 MHz	12 nH	470 MHz	4.7 nH	630 MHz

(* = The layout is critical at these frequencies!)

Table 5. Coils suitable for use with the MAX260x family of VCOs.

Manufacturer	NEOSID	COILCRAFT	TOKO
Distributor	Sterling Components	Coilcraft Europe	B.E.C. or Roxburgh
Airspaced	SM-L1.5 (5.3 - 43 nH)	Micro Spring (1.6 - 12 nH)	33CS (6.8 - 22 nH)
		Mini Spring (2.5 - 43 nH)	36CS (22 - 50 nH)
		Midi Spring (22 - 120 nH)	
		Maxi Spring (90-538 nH)	
SMT inductors	SM-1206 (6.8 - 150 nH)	0805HQ (2.5-51 nH)	LL1608FS (1.2 - 270 nH)
	SM-NE29 (10 - 1000 nH)	1008HQ (3-100 nH)	LL2012FH (1.5 -680 nH)
	SM-NE45 (100 - 2200 nH)	1206CS (10-1200 nH)	FSLM2520 (100 - 2200 nH)
		1812CS (1.2-33 uH)	

To sum up

The MAX260x series of oscillators are ideal for applications requiring a fixed frequency oscillator or narrow band VCO. Development time is kept to a minimum and its 6-pin SMD package takes up a tiny area of the PCB compared to a discrete oscillator design. An external inductor is the only component necessary to define the oscillator centre frequency. The inductor characteristics are not especially critical and can be obtained from many suppliers.

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Web links

MAXIM:	www.maxim-ic.com
Coilcraft:	www.coilcraft.com
Toko:	www.tokoam.com
Neosid:	www.neosid.com
BEC:	www.bonex.co.uk.
Sterling components:	www.sterling-comp.co.uk.